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BBN Technologies

ONR STEM Grand Challenge
Extensible Adaptive System for STEM Learning

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Cognitive Task Analysis v1.0

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Dr. Rohit Kumar Raytheon BBN Technologies 10 Moulton St. Cambridge, MA 02138-1119 Ph: (617) 873-2038 E-Mail: rkumar@bbn.com	Office of Naval Research 875 North Randolph St. Attn: Joseph Cohn ONR Code:341 Arlington, VA 22203-1995 Ref: Contract N00014-12-C-0535 E-Mail: joseph.cohn@navy.mil **Cc:** Timothy.Keenan@dcma.mil (ACO) reports@library.nrl.navy.mil tr@dtic.mil barthom@onr.navy.mil ray.perez@navy.mil Brent.olde@navy.mil

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1 Introduction

This is the Cognitive Task Analysis (CTA) report (CDRL Data Item #A006) for EAITS, an extensible and adaptive STEM Learning System that BBN is developing under the ONR STEM Grand Challenge (GC) Program, Contract # N00014-12-C-0535.

EAITS Phase I CTA (i.e., prior to human subjects research authorization) focuses on identifying aspects of CTA suitable for the overall system concept (Ref: System Concept/Specification Report #A003) and planning for the Phase II CTA. During Phase II, we plan to conduct the CTA in two stages. First, we will focus on the primary learning activity employed by our system (problem-solving) in the context of in-domains problems. During this stage, the choice of learning environments will be set aside to study the fundamental cognitive processes a learner applies while solving SAT Physics problems. Insights from this stage will be used to improve the EAITS learning environment being developed. The second stage of CTA will focus on studying problem solving within our learning environment. Observations at this stage will help us determine how well our learning environment aligns with underlying cognitive processes. Furthermore, the second stage CTA will overlap with preliminary usability testing of our system.

Section 2 describes a preliminary model of the problem solving learning activity. Section 3 describes our plans for applying an iterative CTA procedure for each of the two stages described above.

2 Preliminary Model

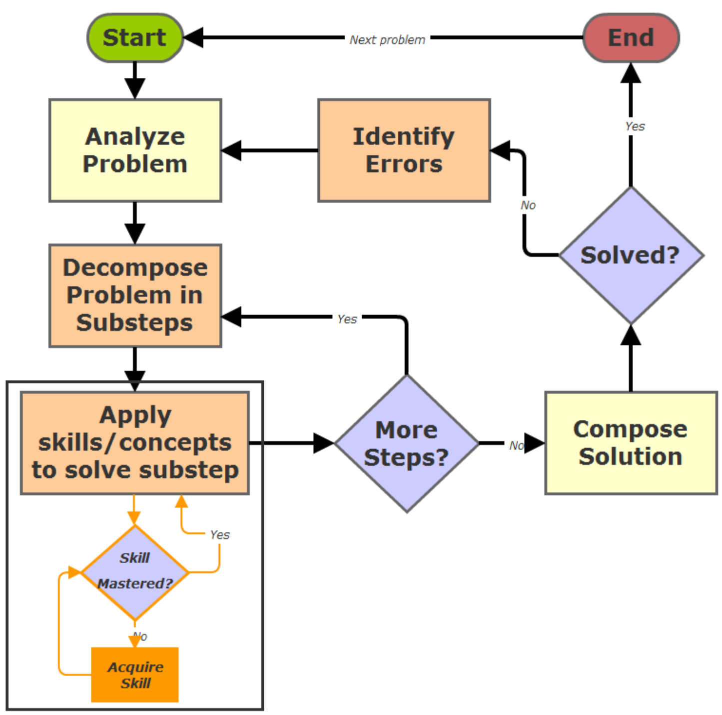

Figure 1. Task Diagram of SAT Physics Problem-Solving Activity

We intend to use Cognitive Task Analysis (CTA) primarily as a method for informing and improving the design of our learning system. We have adopted a simplified approach to CTA to enable us to efficiently iterate through multiple cycles of design, development, and (formal as well as informal) user-testing. In this approach, we start from a preliminary model of the SAT Physics problem-solving learning activity shown in Figure 1.

Analyze problem: The problem solving activity starts with an analysis of the problem. The learner identifies the objective of the problem and enumerates potential approaches to solve the problem. Unlike problem solving in a design setting, typically there are only a small number of applicable approaches. In a time constrained SAT Physics problem solving setting, it is crucial that the learner quickly selects an approach and proceed to the next step.

Decompose problem into sub-steps: The learner identifies the sequence of sub-steps involved in applying the approach to solving the problem. Typically, this is performed in an incremental manner where not all sub-steps are enumerated in advance, but instead are determined as the learner proceeds further. We believe this is one of the key cognitive process that a problem-solving based learning system should support.

Apply skills/concepts to solve sub-step: The learner recalls previously mastered skills and applies them to making progress on the sub-step at hand. At this point, the learner may not have mastered the required skills or may make an error (*slip*) in the application of the skill. Both of these possibilities must be readily supported within the learning environment by making relevant instructional content (such as dialogs, videos, etc.) available to the learner as well as providing timely assessment/feedback in case of a *slip*.

Compose solution: After completing all the sub-steps involved in the chosen approach, the learner composes the solutions to each sub-step into a singular solution to the problem. As in the case of analysis of the problem, this step could be very demanding in the generalized problem solving activity. However, due to the nature of SAT Physics problems, we believe this step usually has minimal cognitive load associated with it in our application.

Identify Errors: Within time bounds, the learner may consider alternative approaches to solve the problem that may rectify errors in the application of the approaches pursued so far. This step in the problem solving activity allows the learner to reflect on the approach pursued which could be crucial for the learning process.

Note that each process shown in Figure 1 is supported by different components in our current system design. For example, decomposition of a problem is supported by making on-demand problem solving help available to the learner. Similarly, system capabilities such as automated assessment, access to integrated multimedia content and system initiated reflective dialogs support other processes depicted in the task diagram.

As we move forward with the validation and refinement of this CTA (discussed in the next section), we will also refine our system design and implementation. This is central to our iterative approach where our preliminary CTA informs our preliminary system design.

3 Plan for conducting Cognitive Task Analysis

As discussed in Section 1, our next steps for CTA will be divided into two stages. In the first stage, we will validate the preliminary model of problem-solving learning activity described in Section 2 using Think Aloud methods in the context of a SAT Physics problem-solving task. A small set of subjects will be asked to solve 3-5 SAT Physics problems (from the topics of Electromagnetism & DC circuits) on paper. The subjects will be asked to describe their thought process through the task. Furthermore, a human tutor (subject matter expert) will be made available to answer conceptual questions as well as provide hints and feedback when the subject is unable to proceed further while solving the problem. We will make observations about the time spent as well as need for help along each of the process depicted in Figure 1. Also, any additional cognitive process not depicted in our preliminary model will be identified and incorporated into the CTA at this stage. The model update and validation cycle may be iterated if necessary.

The second stage of CTA will focus on validation of the refined CTA from Stage 1 in the context of the problem-solving using our system implementation at the time. Similar to the first stage, a small set of subjects will solve 3-5 SAT Physics problems using our learning environment. The learner will be able to use the different features of the system including multiple forms of support, access to instructional content and automated assessment while solving problems in the learning environment. CTA validation and refinement at this stage will primarily focus on identifying the differences between problem-solving on paper vs. in an online learning environment in terms of metrics such as time spent and help needed.

The refined CTA obtained after these two stages will serve as the reference model for making final design modification to our learning system before proceeding to first formal evaluation of the system during Phase II of this effort.

